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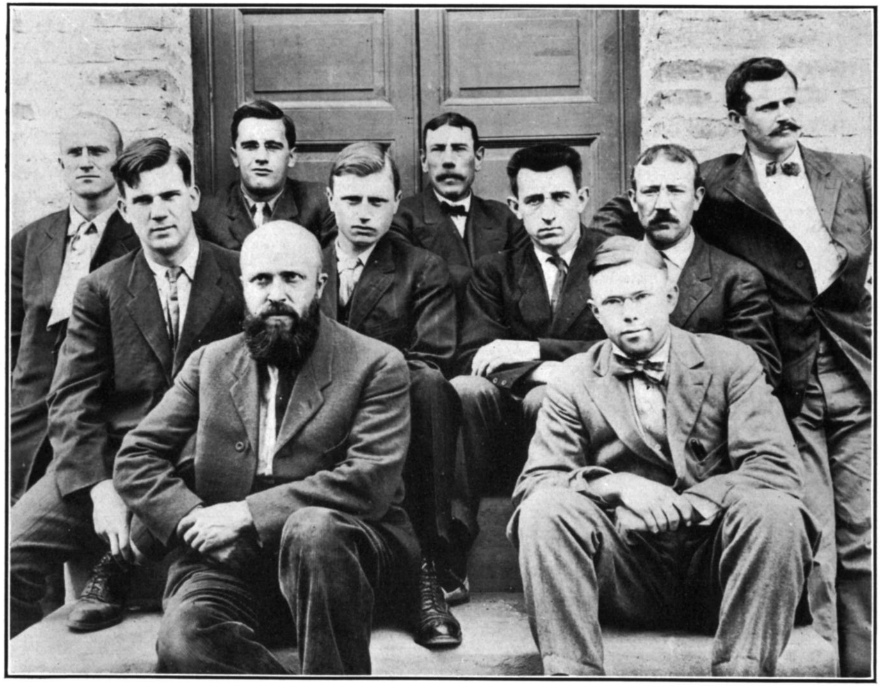


THE STAFF OF THE SAN LUIS OBSERVATORY, 1909.

THE SAN LUIS OBSERVATORY OF THE CARNEGIE INSTITUTION.

By R. H. Tucker.

An astronomical expedition for the purpose of determining star positions with a meridian circle presents some features of novelty, since work of this class is usually confined strictly to the large establishments of permanent character. This is especially notable when the plan of observing includes fundamental determinations, which form a considerable part of the San Luis program. The technical description of the work, and the detailed results will eventually be included in the special reports of the Department of Meridian Astrometry of the Carnegie Institution. Some description of the aims and history of the expedition, and of the conditions under which the work was accomplished can be given in these pages, without conflicting with other more elaborate presentation of the scheme and its issues.

The many eclipse expeditions that have been in the main successful, originated and carried out by the Lick Observatory, resemble in some of their features this late expedition in another branch of astronomy. The eclipse parties have been described in this publication, in some of the most interesting and attractive articles that have appeared; the splendid photographs secured of beautiful and strange regions of the world, of specially designed apparatus, and of the eclipse phenomena, all combine to present a striking picture of what is truly the romance of astronomy. Though it might so appear, there has been nothing impromptu in the development of these expeditions; on the contrary, they have been the result of plans begun long before the date of the eclipse, of extensive and long-continued preparations, of unremitting energy and attention to details up to the moment of the passing of the eventful day. And thereafter, the completion of the plan includes the return transportation of all the apparatus, unpacking, distributing and setting up of much of it, and the discussion of the photographs, fruit of many climes, usually tropical in character.

The San Luis expedition has a similar history, with all the main features of an equally strenuous nature, in general maintained for a much longer period. Instead of a few weeks of forced pressure in preparation, and a day of high tension, much more extensive construction was to be undertaken, and finished with celerity to be ready on a date fixed by the arrival of the staff, who would be prepared to begin observations; and the tension of the observing itself was to be kept high, for a period of nearly two years. The fruits of the expedition will require a much longer period to mature, and will appear in the form of a catalogue of the places of the principal southern stars. The plan of completing a homogeneous scheme of observation of all the principal stars, from one pole of the heavens to the other, all the observations to be made with the same instrument, and these to be reduced and combined by the same methods, had been under discussion for fifteen years. It was originated and put into execution by Professor LEWIS BOSS of the Dudley Observatory, Director of the Department of Meridian Astrometry of the Carnegie Institution. Some ten thousand observations of northern stars had already been made at Albany with this instrument, as part of the comprehensive plan, before the expedition for observing the southern stars was started. The remaining observations in the northern sky are planned for the future, to complete the entire scheme, the southern part of which has been definitely and successfully finished.

Six years ago, when Professor Boss found that he could not personally take up the execution of the work in the southern hemisphere, he decided to ask co-operation, and to put the active prosecution of the southern scheme into other hands. Various countries were considered as possible sites for the temporary observatory, on three separate continents; but, for numerous reasons, the Argentine Republic seemed to present the most advantages. The conditions under which the work at San Luis was accomplished confirm the conclusions of previous experience, as to suitability of sky and climate—both nearly, but not entirely synonymous—for an extensive series of astronomical observations of high degree of excellence. It is possible to select a site where for short periods, or during certain seasons, there may be exceptional advantages for particular lines of astronomical work. A mountain summit often has peculiar points of excellence. But the high mountains cannot usually be continuously occupied, and the difficulty of access, at all times, would always be an obstacle. The Lick Observatory has observing conditions in the best months of summer that, in all probability, are not surpassed to any great degree by any available observatory site. They extend through the entire summer, rarely interrupted by any really bad observing conditions. But, in contrast, there are long storms in winter, and in most years there are intervals of several weeks, often several such intervals, when no observing of any character can be done. This will be true, to greater or less extent, of nearly all the permanent observatory establishments in this country. And in the northern parts of the country the severity of the winter climate makes the prosecution of astronomical observations a test of physical endurance, which must be counted as an element in the night's work.

The record of close to three hundred nights in the first year of the establishment at San Luis, on which observations could be made during at least half the night, tells its own story of climatic conditions for continuous extended opportunities for observing. This is essential in large schemes of meridian-circle observation; each part of the sky comes in turn under scrutiny, and if the whole night is necessarily employed at all seasons, there is no opportunity to make up, by observing in extra hours, to fill gaps which occur during bad weather. Two-thirds of the nights on which observing could be done, or two hundred nights in the first year, were practically clear throughout, and observing was not often interrupted by temporary cloudiness on nights employed for observations. The record of clear sky is not quite complete, since no particular note was taken of the nights, and half nights, for which observations were not scheduled. Thus, at the beginning no observing was done on Sunday nights, and no note was made of the sky on those nights. After the first two months, the last half of Saturday nights and the first half of Sunday nights were not used, still keeping an average of twelve half-nights per week; and an occasional holiday was not scheduled. The actual record of the first year shows that observations were made upon 283 dates, above 80 per cent of the nights scheduled; and 152 nights were used throughout, or 58 per cent of those scheduled. In this first year 60,900 observations were made. If the reckoning be taken of a full calendar year, beginning two months later, the record gives 63,100 observations, on 290 nights. This record of complete meridian-circle observations has never been exceeded, and probably will not be surpassed in the future. In general, 70 per cent of the time scheduled for observing was actually employed for satisfactory work. Several calendar months furnished from twenty-six to twenty-eight available nights, including some in both summer and winter seasons; and, in one case at least, twenty-eight successive nights were utilized. The smallest number in any month was eighteen, in September.

And there is another side to the consideration of climate: there were no nights, in summer or winter, when observing entailed any degree of physical discomfort. There were no stifling, oppressive hot nights, and no nights so cold that the active movements necessary in keeping pace with the successive star passages were not sufficient to keep up circulation, with light warm clothing, at temperatures only two or three degrees below freezing. There was no snow, beyond slight flurries in the air on an occasional winter day, though the neighboring mountains, two to three thousand feet above us in altitude, used to exhibit coverings of snow in summer as well as winter. In regard to the character of the sky and the "seeing," the nature of our work does not call for the highest degree of excellence at all times. Clearness is essential at most times, for the list includes many stars of the faintest ever observed by meridian circles; and in the daytime the least perceptible amount of thin cloud is sufficient to obscure entirely the greater part of the stars for which daylight observations are needed. Steadiness is greatly to be desired, for the observations principally, at low altitudes, for refraction investigation. That we obtained these last in very large numbers is sufficient test of the possibility of observing at low altitudes. If the observations at low altitudes were sometimes unsatisfactory at the time, this may have been due to conditions local to the observing room, quite as much as to the natural unsteadiness of the atmosphere. In place of a steel building of modern design, as had been originally planned for the San Luis work, it was finally only possible to put up an observing room of brick, in the time and under the conditions imposed. The conditions of the atmosphere immediately surrounding the telescope produce well recognized effects upon the steadiness of the images, and these conditions were not expected to be of the best in the character of building adopted. Any comparison is likely to be influenced by personal experience, but it may be confidently stated that while the best conditions at San Luis were not as good as the best that are experienced at Mount Hamilton, there was a better distribution of good observing nights; and the number was much greater, and the quality better than are known at any of the observatories situated like that at Albany. The record of observing alone cannot be relied upon to establish these points, and the resulting precision of the observations has, combined with atmospheric conditions, other elements to be considered. It is probable that the San Luis observations will be found to satisfy all reasonable requirements, without any allowance being made for the great number which were obtained, nor for the rapidity with which they were accumulated.

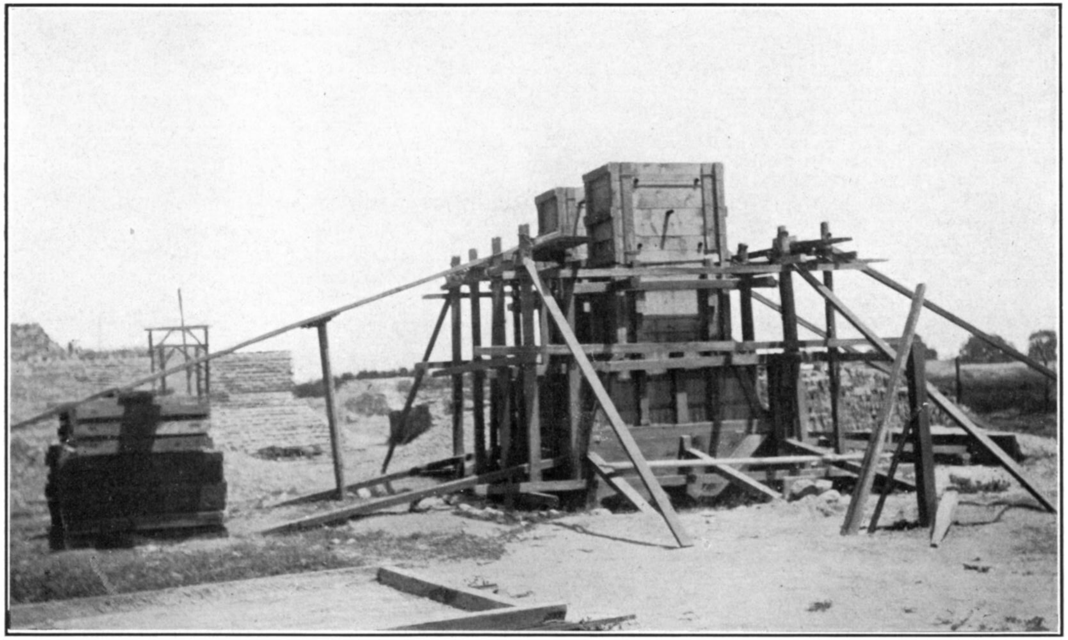
Some space must be given to this matter of climate and observing conditions, for there is no question about this expedition which has been more often asked by those interested in any degree, and it would be a point of prime importance to any astronomer in discussing plans for establishing an astronomical station. The climate must always be considered, in planning for the housing of the staff in an expedition, and, even for temporary occupation, the character of the dwelling required may be an important point in making the decision. San Luis has been visited by violent hail storms, with high winds, in summer, and a substantial housing of instruments and of staff was required. Yet, during construction, we lived for five months during one summer in tents, pitched alongside the site of the observatory, and suffered no hardship thereby. It may be confessed that there were nights when we feared for our guy ropes, and the hail beat fiercely upon canvas roofs, but the guy ropes held, and the double roofs protected our heads at the worst. The house could be built for nearly an open-air manner of life, shelter from winds, shade from direct sun, but no great fortification against cold, which was no enemy of any person already accustomed to fresh air and good ventilation. Our house was only constructed for temporary occupation, though it was not expected that we should endure any actual hardship in the course of our life there; it met our needs, and at the close of our work was left in condition perfectly suitable for further use. The walls were of brick, the roof of wood with rubberoid covering, doors and windows were planned to be opposite each other, the former opening directly upon the covered corridors each side, and the latter opening inward like double doors, in the manner universal in the country, sliding sashes being practically unknown.

A final illustration of the character of the climate might be drawn from the use of the tennis court, which, while not of astronomical importance, was laid out during the construction epoch as a profitable adjunct to the life of a staff of energetic Americans who believe in active, clean exercise, for the promotion of good spirits and physical fitness. There were probably not a dozen days during the first year after the arrival of the staff that the court was not actually in use; the storms in the rainy season were generally of brief duration, the night was likely to be the stormy period, the gravel court drained promptly, and finally there were no "blue laws" in that land of liberal customs, to enforce a residence between four stone walls, for the enjoyment of a game of tennis or golf on whatever day one wished to play. If on the other hand one chose to ride to the open country, for a day after the small partridge, throughout the winter one never had to take account of the weather; it might be briskly cold for part of the day, it might prove hot in the noon hours, but the dry air and the nearly certain bright sky would make either condition far from unendurable in the wide open. Cloudy sky might follow at night, symptoms of undeveloped storms, most likely to be present, however, at the changing of the season from wet to dry, or the reverse.

The country east of the Andes has the rainy season in summer, which is a far better combination than the prevailing winter rains of the West coast. The rains moderate the heat of summer, and fall when vegetation most needs it, while the nearly continuous fair weather of winter makes the cold easy to endure. Californians should be able to appreciate such a contrast of climate, by transferring the dry weather of the midsummer to the opposite season of the year. In the summer season, one had to take chances of sudden and severe squalls. Probably none of the staff will forget the hail and wind that descended upon their heads, one New Years night at Trapiche, though both combined could not drive the hardier ones to abandon the tent, for shelter within the mud walls of the neighboring ranch houses. One year later, the passing of the old year was celebrated at Piedra Blanca, by a diminished staff, under ideal conditions; dining out of doors, by the light of Chinese lanterns, at the camp of a cosmopolitan party of engineers, the chief of which, a friend of twenty years ago, included among his attainments an observatory experience of no mean value. These trips each involved a horseback ride of about thirty miles and return, mainly over high rolling pampa, with the range of mountains on one hand, and hundreds of miles of open country on the other. When once broken in, such a ride was a delightful change from observatory routine. These incidents, among many similar ones, are recalled here in the record of our life at San Luis, for the force was vigorous in its makeup, and not always devoted to strenuous work to the exclusion of all else; with this, was mingled the pursuit of healthy pleasures of no less strenuous form. We are learning the value of good health, as a positive asset in the production of results. Every one indulged in riding, and every member of the force owned a saddle horse. Golf was played one season, but the alfalfa fields were rather too uneven, though close cropped at midwinter; and the sandy stretches of the river bed were not found to be stimulating enough for the pursuit of the flying ball. Baseball was practiced on the neighboring football field, first belonging to the boys of the normal school, and later occupied by the soldiers of the sixteenth regiment of the line. There were only a few English neighbors, from the Pacific Railway, with whom to share these pursuits; and while the Argentine youth are developing a good game of association football, their elders and the great proportion of the population probably still regard these exercises as harmless indication of incipient lunacy, to which men of Anglo-Saxon descent are liable. But with it all, there could have been no one, acquainted to any degree with our real work, that failed to recognize its serious character, and the devotion which was given to its prosecution by the staff. The evidences of such appreciation on the part of our many friends, of all nationalities, proved a stimulus of the right sort, to keep us from flagging on the route we had laid out to follow. It requires no stretch of sentiment to believe that the Puntanos, the natives of that city, were proud to have the observatory located in their midst, nor that their welcome to us was very sincere, nor that they regretted our departure when our work was done.

But it is time to return on our track to the preliminary steps. The active preparations began in July, 1908, when the construction of the roof shutters, and the molds for the concrete piers was taken up, in Albany. For this purpose a large empty skating rink, near the Dudley Observatory, was occupied by a force of several carpenters. Since expert carpenter work is difficult to obtain in countries and cities where buildings are mainly of brick, burned or in adobe form, it was decided to prepare the more complicated parts in advance. The men employed were skillful, followed every suggestion expertly, and showed keen interest in the finished roof and molds, and in the purposes for which they were designed. Good masonry work could be relied upon in the country where so much of it is done, but iron work, and wood construction are more difficult to find.

Once completed, the separate parts were packed for shipment. Sets of rails and girders for the support of the floor of the observatory, and for the observing chair, the reversing carriage and the mercury basin, were also prepared for shipment. The first expedition, besides the construction materials, carried only a field transit for locating the lines, with a chronometer for field work, and one of the fine astronomical clocks, for security against accident to either in transportation. The meridian circle, both chronographs and the other clock were brought out



CONSTRUCTION OF CONCRETE PIERS FOR THE MERIDIAN CIRCLE.

by the second party, when the observatory was ready for their installation and service.

There is practically but one steamship line, at present, from New York to Buenos Aires, that can be relied upon for convenient, direct, and reasonably comfortable service. This is the English Lamport and Holt line, which despatches one direct steamer a month, and an intermediate ship that goes as far as Rio Janeiro, where passengers and mails are transferred to one of the lines from Europe to Buenos Aires. There are several lines that send freight boats from this country to the River Plate, but their dates of sailing are irregular and subject to change, and the voyage is apt to be slow and of uncertain duration. Their passenger accommodations are usually very limited, but often good in many ships. The L. & H. steamers are some of them as large as any that call at Buenos Aires, they are not fast, but make voyages of nearly uniform length. The accommodations on the best of them are of modern design, especially suitable for tropical voyages, and the masters and officers are almost universally popular, and much liked by those that travel in those waters. With our large amounts of freight, on both trips down, transhipment at Rio was necessarily to be avoided, and both parties sailed by the direct steamers.

The first party, including Professor Boss, and Messrs. VARNUM and TUCKER, sailed from New York on the *Velasquez*, Captain KELLY, on August 20th, and reached Buenos Aires after a voyage of twenty-four days. This ship, a comparatively new one, of 12,000 tons, was lost on the return voyage to New York, having run off her proper course between the islands of the Brazilian coast, on a stormy night, striking upon the southern end of San Sebastian Island, not far from the mainland. The passengers with their personal baggage and the mails were saved, but the ship and cargo were a total loss. The captain died a few months later, never having recovered from the strain, mental and physical, consequent upon the loss of his ship. The usual voyage through those tropical seas is serene, and apparently secure. But chances must often be taken in navigating down the coast, and near harbors, of which most of us are probably generally unaware. Going south the steamers touch at Bahia, Rio, and Santos, in Brazil, and call at Montevideo, thence crossing the wide river, to enter finally the great docks of recent construction at Buenos Aires.

All these ports prove interesting, whether it be a first visit, or a renewal of old acquaintance. All have shared in the recent stimulus of modern improvements, after some generations of slow progress. Rio Janeiro has a new avenue cut through the city, on the plan of the Paris Boulevards, to beautify it, and to open the congested part to traffic and fresh air. In this step, the city of Buenos Aires had previously set the pace. The Brazilian cities have been cleaned, and the yellow fever has been pretty well stamped out by modern sanitation and health measures. Santos had undoubtedly the worst reputation for unhealthiness, at one epoch, of any important shipping port in this hemisphere. Fine stone dock walls line its shore, at which steamers lie, two and three deep, awaiting turn to load coffee. In Rio, Bahia, and Montevideo ships lie at anchor, and discharge cargoes in lighters. One has usually a day for each of the ports of call, and sometimes a longer stay permits a run inland from the city. Trolley cars and automobiles are abundant, where twenty-five years ago the mule tramway provided the principal mode of getting about. Carriage hire has, however, always been moderate in price in most of these cities, in comparison with the North American large cities; and much use is still made of public carriages, though the stock and equipment are often poor in quality. Much of the life of the cities centers about the open-air cafés and the restaurants, which may be found of all grades. On the return trips the L. & H. steamers also call in the West Indies, at Barbadoes, and perhaps Trinidad, both very delightful places to visit.

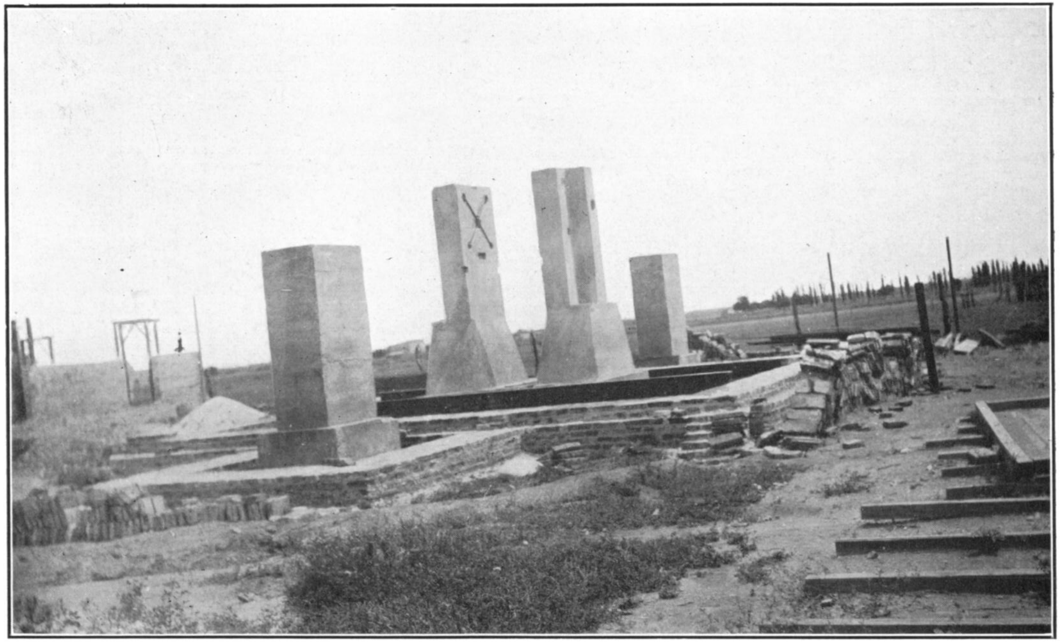
The transportation of the first load of freight was managed in much the same manner that has been followed by the Lick eclipse parties. Every parcel was checked off by number as it went on the carts, again as it was transferred to the night boat at Albany, again as it was put on the lighter alongside in New York, and no piece was lost sight of until it had crossed to the Brooklyn side, where it was again checked as it was passed to the dock of the ocean steamers. In Buenos Aires were splendid facilities for unloading. The Argentine Government, through the Ministry of Agriculture, passed all our freight without customs examination of any character, and the individual parcels never touched the dock at all, but were swung directly from the ship to the car, which carried the entire lot as its only load. Checked again here, and at the unloading and at the deposit in San Luis, no single parcel could go astray and no damage could occur without its being known at the time.

The city of San Luis had been decided upon for the site of the observatory, when the expedition started, so the freight was promptly despatched in locked car, while the members of the party had a few days at their disposal in Buenos Aires. A more southern location, at a latitude more nearly equal to the 42° North, of Albany, would have been desirable in some respects. But it was certain that the southern Argentine provinces would have much greater rainfall, and undoubtedly less advantages of sky and climate. It was essential to select some city of easy communication, and where facilities for construction, and for comfortable existence would be found. No extreme southern locality, in the other countries considered, appeared to present any superior advantages. During our stay in the capital city of the Republic, official calls were made upon the Minister of Foreign Affairs, Dr. DE LA PLAZA, formerly Argentine Minister to this country, and later on, during our residence, elected Vice-President of the Republic; upon Dr. ROMULO NAON, Minister of Public Education, now representing his country as Minister in Washington; and upon Dr. PEDRO ESCURRA, Minister of Agriculture, in whom an old friend was encountered, and to whose department the expedition was greatly indebted for favors in landing, and for the transportation of all our party and of the freight to San Luis. With Mr. WALTER G. DAVIS, chief of the Argentine Weather Bureau under the Department of Agriculture, was renewed a friendship of over twenty years' standing, and from him the expedition received favors of a personal and official character which are beyond the possibility of acknowledgment in adequate form here. He had been previously consulted during his visit to this country, two years earlier, in regard to the choice of site, and had in the meantime personally visited the location which was finally adopted. His friendly offices on our behalf ended only with the departure of the last member of the expedition from the shores of the River Plate; and his own long personal experience in astronomical work made his advice and assistance especially valuable.

The city of San Luis, capital of the Province of the same name, lies upon the old direct route to Chile, five hundred miles from Buenos Aires. Before the days of railways, and while the rails extended only as far as Villa Mercedes, stages carried mails and passengers from San Luis west to the Uspallata Pass, on the way to Santiago and Valparaiso. The level of the country rises steadily, but so gradually as to be nearly imperceptible in traveling, until at San Luis the altitude is about 2,500 feet. South of the city, the country is not so elevated, and a new branch of the Pacific Railway was completed during our stay, and the direct travel from Buenos Aires to Chile now passes over the southern line. A great extent of wooded area begins just before reaching San Luis, after passing through the open pampa country which extends south for many hundred miles.

Twenty miles to the south of the city there is a salt lake, whose waters are as condensed as those of our own Great Salt Lake; there are minerals, some gold, fine deposits of mica, and good building stone in the neighborhood of the capital city of the province. The river carries a large volume of water only in seasons of freshet, but streams from the small range of mountains, east of the city, provide a constant flow for water supply, and for irrigation. We were able to supply our house from the city pipes, which are still under National management, after an interval of new construction; and we used the water from the irrigation canal for our building operations, having applied directly to the Intendente for permission to take the water any day that we needed it. The existence of the small rivers, which usually end their courses by evaporation and filtration, throughout the country, gave birth generally to the first colonies; and it is difficult to realize that small cities, like San Luis, are older than any in existence in our own country.

There is on electric light plant, but its lines did not extend near enough to our location for us to make connections, when the observatory was built. We used a small battery to provide



FINISHED PIERS, WITH FLOOR RAILS IN POSITION.

electric light for the mire, and relied upon kerosene for the lighting of observatory and dwelling. We were located about a mile from the center of town, and one of our last projects was to run the lines to connect us with the post office, the position of which had also been once determined by astronomical observation. The lines were run early in the morning, so as not to be interrupted by traffic; and we had a party for the purpose, made up almost entirely of engineers, for instrument, notes, rod-men, and "chain gang." Our force was, in fact, competent to take up nearly any line of work; and it fortunately included one man better skilled in fine clock work than any one to be found in the city. In modern scientific work, something more than special attainments in a special subject is often required; some knowledge of engineering, and of practical building operations may be useful, exact bookkeeping, and familiarity with the usual forms of commercial transactions are often needed, machine work and carpenter work are to be planned, and the repairs of instruments may be dependent upon individual skill.

Upon our arrival in San Luis we were met at the railway station by a number of prominent men, who gave us a courteous welcome, and accompanied the party to our hotel. Special mention should be made of the first one to greet us, Dr. MODESTO QUIROGA, then Minister of Government for the Province, graduate of Cornell University, a man of many accomplishments, whose warm-hearted manner and sincere character had made him hosts of friends among his own people, and who was to be our cordial and intimate friend, to the close of our stay. The kaleidoscopic changes, to which party government is subject in the provinces, soon after threw him out of power, but that made no differenec in his personal activity for the welfare of his own people, nor in the cheerful and energetic devotion he gave to his friends. His hand was the last to be pressed in good-bye, among those of many friends at the departure from San Luis. The day of our arrival, the twentieth of September, proved to be the national feast day of the Italians, of whom there are large numbers in all the Argentine cities. We accordingly called upon the Italian Consul, and met there many of the men prominent in official life, including the acting Governor, and the Chief of Police. At night we joined the party of guests in the official box at the theater, at the performance which was given by members of the Italian colony, for the benefit of the mutual aid society of that nationality. This function did not end until two o'clock in the morning, when we were finally escorted to the hotel Mitre, by our hosts. Previously we had been guests at breakfast of Mr. CECIL NEWTON, the English Director of the National Normal School for boys; and we had been entertained at dinner at the Hotel Pringles by Doctor QUIROGA, with a large party of official friends. During the afternoon we had visited the future site of the observatory, on the grounds of the Normal School, and had driven out to the railroad cutting, to look at the general character of the subsoil, so that altogether it had been a full day, the first of our expedition in San Luis.

The selection of the site on the grounds of the school proved to have a happy side, as it brought us into intimate relations with Mr. NEWTON, who was an unfailing friend to the expedition during all the time that he remained in San Luis at the head of the school. Reticent in promises, everything that was in his power to do for us was performed in the most thorough and unostentatious manner. He later became Director of the new Carlos Pellegrini School for boys, at Pilar, in the province of Buenos Aires, a fine big establishment, to be conducted for the Argentine youth on the plan of the great English public schools. Such success, in that new field, as is due to high principles, and personal efficiency, may be confidently predicted for the new school. The big building, which housed a large part of the boys of the Normal School, and in which we took our meals during the epoch of construction, was later abandoned for school purposes, and was finally occupied as barracks for the recruits of the sixteenth regiment of the line.

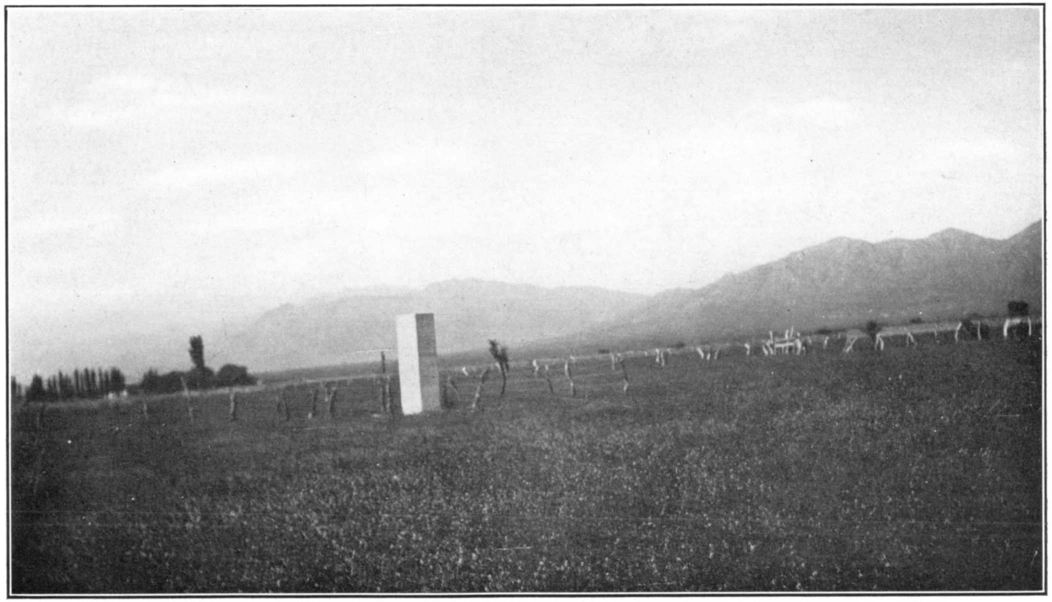
In respect to natural conditions, the site of the observatory was well adapted to our work. Fields of growing alfalfa surrounded us on all sides, this being fed off at maturity by large droves of cattle, horses and mules, then irrigated and left to grow again, each section being thus used alternately. The fields were of convenient use for our own horses, and these could be left at liberty within the enclosures, day and night, throughout the year, on the payment of pasturage fees. The roads, which were very dusty for most of the year, were several hundred yards distant on at least three sides, and lines of trees and the orchard of the school were shady improvements in the view. The railroad was a quarter of a mile north of us, but the disturbance of passing trains never was noticeable, the gravelly nature of the subsoil being a bad conductor of vibrations.

The growing alfalfa reduced the radiation from the surface of the ground, especially during the daytime, when many of our observations were secured. The land was practically level in all directions about us, but a walk of an hour east, through the thick brush, would bring one to the foot of the mountains, whose summits were in turn mostly explored by the men on the force.

Four days after arrival, lines had been determined by observations of the sun, sufficiently accurate for the laying out of the foundations of the dwelling, which was to fit into the plans of the establishment. The ground to be occupied, about a hectare in amount, was wired off, and a small building of corrugated zinc was built, as a store house. This was eventually retained, for the same purpose, throughout our residence. Brick, sand, lime, stone, and lumber were purchased in the city, provision being made for hauling by mule carts, and cement was ordered from Buenos Aires. We had obtained, in this country, a list of good foreign cements, and one of the selected marks was found to be on sale, though it could not be purchased in San Luis. The freight usually required a week to come from Buenos Aires, and on only one occasion—the final dispatch of our equipment—was this time much exceeded.

After having seen the site of the future observatory, Professor Boss left San Luis early in October, to spend a few days in Buenos Aires, before returning to this country. The last day of his stay with us was celebrated by the placing in position, in the foundation walls of the establishment, of the first piece of stone used in construction. For reason of the strong tendency towards filtration upwards of the alkali salts of the soil, in that region, buildings of the best class have usually foundations entirely of stone. A coating of cement was laid upon our brick foundation walls, but as the filtration follows often the face of the wall, this is not a sufficient remedy. The result rarely goes beyond the discoloration of the wall face, however, though porous brick may suffer some slight deterioration.

In order to be always conveniently near the work, we pitched camp alongside the site, having two wall tents, for the office and sleeping accommodations, and a small conical tent for the watchman, who was later to act as porter for the observatory. Our plans called for an observatory building of brick, with wood roof and shutters, the piers for the meridian circle and for auxiliary apparatus of reinforced concrete, and a dwelling for the residence of at least seven men, though the full staff later included ten. The observatory was of the same dimensions as the Albany building, and the piers were necessarily exact reproductions, in concrete, of the granite monoliths that had been used in the northern establishment. The greatest care and exactness had to be exercised in the construction of the piers, for there could be no possible readjustment made, once the building of them had been advanced. Strong and precisely made molds, such as were designed at the start, were necessary, to hold the concrete construction rigorously to the lines required. There could be no later shifting in the points of support of the meridian circle, which must be accurately leveled, and revolve truly in the plant of the meridian. The actual support of the instrument was practically one solid block at the finish; made up, first, of a concrete base one foot thick and of the full size of the excavation; on this a block rising above the level of the ground, then two piers, built simultaneously to the full height, and joined, as integral parts, to the lower blocks. The molds of the upper piers could be shifted to fit requirements, by the aid of the field instrument, and with the base lines already determined. Such exactness is not ordinarily required in concrete work, and no precautions or tests were superfluous for ensuring the needed precision. Observations of circumpolar stars were the main reliance for the determination of the meridian, and were repeated at various times during the construction, but observations of the sun for the time, and for latitude and azimuth, were also made. The field transit was provided with a diagonal eye piece, for taking observations at all altitudes, and with a cap for the objective



CONCRETE PIER FOR THE MIRE, IN THE ALFALFA FIELDS.

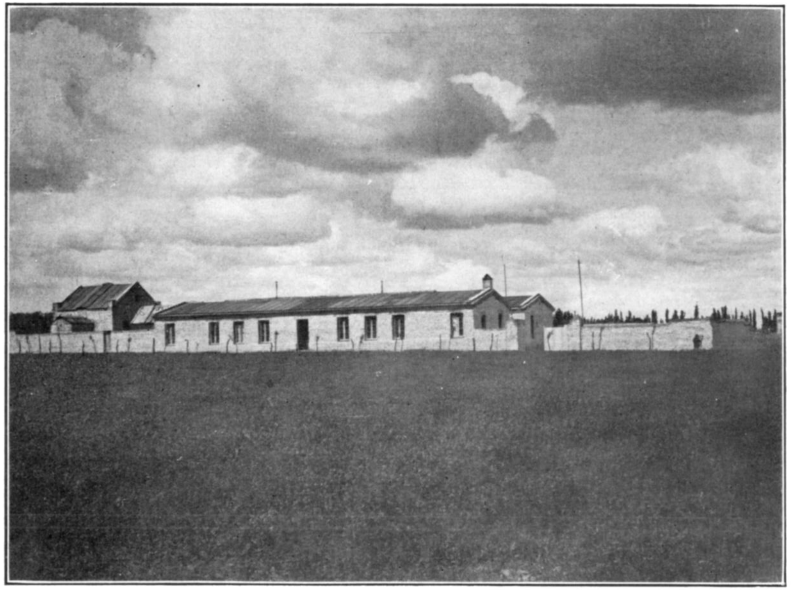
end for reflecting artificial light into the field of view. The permanency of the lines was secured by stakes, set usually a hundred yards or more distant. The meridian-circle piers were finished in November, two months after our arrival. In addition to these, piers of similar construction were built for the two collimators, and for the Mire, and piers inside the office building for each of the two astronomical clocks. The meridian mark, or Mire, one hundred yards north, was to be brought into focus by a lens, mounted on the collimator pier.

The ten cylindrical holes, through the principal piers, for the circle microscopes, and for the axis illumination, were necessarily to be built in exact alignment, especially since the microscopes permitted of very slight adjustment in position or in focus. This object was attained by using iron two-inch tubes, passing through each mold, each tube supporting a solid cylinder of wood, made in two parts, and surrounded by a sheet brass cover, coated with paraffine. On stripping the molds, the iron tube could be withdrawn, the wooden half cylinders, protected from swelling by the metal covers, could be drawn out, and then the thin metal could be unrolled, after the fastening bolts had been unscrewed from the inside.

There were no men employed on the work, masons or helpers, that had ever worked in concrete, though surface cement finish is commonly done by such men as we found; and, for so small a project, the concrete would naturally be mixed by hand. The combination adopted was four of rock, two of sand, and one of cement. The proportion of water is usually a matter partly of experience, and partly of tests upon the spot. The rock was of excellent quality, hard and clean, and was to be obtained from a quarry a couple of miles distant, almost in condition for use, requiring only the breaking of a small proportion of the pieces. The sand was of the best, hauled direct from the river bed, where it was dug from a yard's depth, after having been subjected to filtration and cleansing by years of deposit. Evidently worn from hard rock strata, its quality would have satisfied any engineering specifications. With good materials, and quick work in mixing and placing the concrete, the resulting piers appeared to be hard, homogeneous, and of good surface. The reinforcing rods were prepared in advance, and shipped with the original freight. The placing of these, so as not to interfere with the horizontal holes, nor with other details, had to be planned in advance.

The foundations for the instrument building were begun as soon as the piers were completed, and meantime the dwelling had been going up, the south portion first. The collimator piers were finished the first of December, and the Mire and clock piers were completed two weeks later. The north side of the house had been held back until the concrete piers within its walls were done, but there was no conflict of plans at any stage, the full number of men employed, some twenty-five generally, being always fully occupied. The plastering and painting of the inside walls was done by contract, and the doors and windows were furnished in one order; the balance of the work was by day labor. Efficient supervision was given, especially valuable in the early stages of construction in an unfamiliar city, by M. FLORIS DU FLOS, who was employed through the full period of building operations. The language presented no difficulties, following upon nine years of earlier use, though a new vocabulary was necessarily learned, in the various trades represented during the construction.

In providing the supports of the rail systems for the reversing carriage, the observing chair, and the movable mercury basin, the adjustment had to be carefully planned. These were practically similar systems to those used at Albany, for the same instrument, but it was not possible to build up the piers to fit the rails, the concrete work had to fit from the start. As a precaution for centering, the large rails, which were supported at each end upon the walls of the building, rested there upon flat pieces of iron, so that the last final shifting, if needed for alignment with the instrument in position, could be given to the whole system. The force of the spring at the end of the meridian circle axis might cause a slight change to be needed, and the reversing carriage must necessarily run exactly to its place beneath the telescope. The large floor girders of iron are shown in one of the accompanying photographs, taken when the piers were complete, and the foundations of the building, with the collimator annexes, had been laid. A previous illustration shows the meridian-circle pier molds, in position for the



OBSERVATORY AND DWELLING, FROM THE NORTH.

last of the concrete work. The walls of the dwelling appear, at the left of this, in an early stage. The Mire pier, later covered with a wooden house and surrounded by young poplar trees, shows in another illustration.

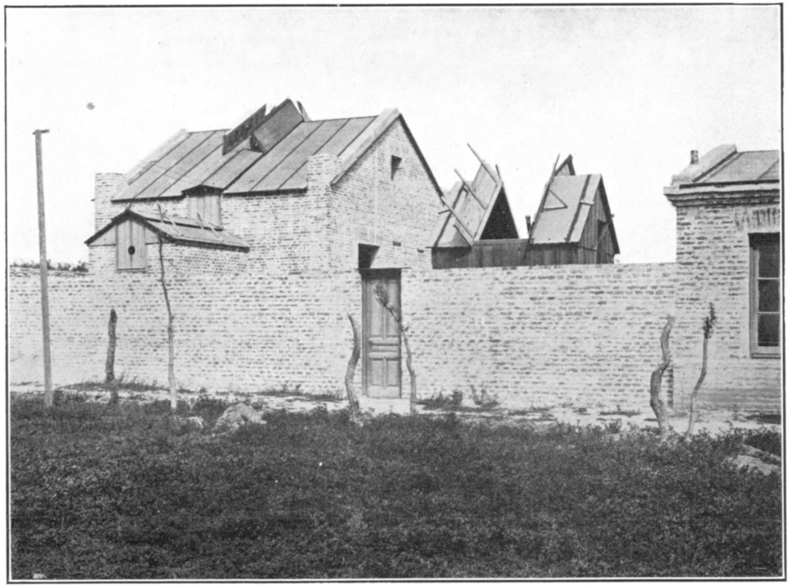
In building the observatory, one side was carried up to the gable before the other was well started, the building being cut into two parts by the opening for the shutters, from the foundation up. The shutters were put in place in January, and the roof entirely finished early in February, in season for the arrival and installation of the instrument. Two illustrations, in these pages, show the establishment entire, and a closer view of the buildings for the instruments. The view of the inner court of the dwelling illustrates the character of the building plan. A photograph of the full staff of the observatory, whose names will appear in another connection, forms a fitting souvenir of the history of the observatory; and the gold medal, which was photographed, along with the accompanying testimonial, for the July number of the *Bulletin of the Pan-American Union,* is also reproduced here. The men originally engaged for the expedition arrived out in February, with Professor Boss, who had made the round trip, including the supervision of the dismounting of the instrument at Albany, in the four months intervening.

Meanwhile the dwelling had been completed, and made ready for the accommodation of the party. Christmas dinner had been eaten in the corridor on the south side, though the preparations for it had been very primitive in character. The house contained eight sleeping rooms, all on the south or shady side, with an extra room, later occupied voluntarily by two of the additional men of the staff, who arrived out in September. There were a dark room for photography, a bath room with tub and shower, and a large storage room, included in this part of the house. Across the inner court, which was open to the sky and planted with trees, which were later to give abundant foliage, was built the other part of the house, of the same outside dimensions, but divided differently. It included a large office, in which six or seven men could work, two smaller offices, each for one man, the clock room, a large closet for papers and spare apparatus, the dining room, with its closet, and the kitchen, and a room for the porter. The closet rooms were a novelty in building in that country, where the absence of such conveniences in household arrangements is often commented upon by strangers.

The first fully prepared meal, with all our outfit complete, and servants ready, was eaten in the new dining room only the day previous to the arrival of the second party. Our preparation could not well have been more precisely timed to fit the conditions. The offices on the north side had the benefit of the best lighting, with the sunshine in the winter, making the need of office fires but little felt, except in the early mornings and in the evenings. The sleeping rooms, opening directly upon the covered corridor, sheltered from direct sun in the hot weather, and from strong winds by the enclosed building, were such as are adapted to the climate, and the doors were practically never closed, in a bachelor establishment, by those who had learned the value of good circulation of air. Stoves were provided for offices and dining room, but the use of fires became less in demand, as the men became accustomed to the climate, and the manner of living which best fits it.

With the second party, which brought the permanent staff up to seven, there came the meridian circle, with all the auxiliary instrumental outfit, the Riefler clock, two chronographs, and the computing forms and stationery. Eight days after the arrival of the freight, the first transits of stars were observed, with the instrument in positon, though the mounting of all parts was not then complete. Quite a full assortment of electrical apparatus had been included: there were circuits for both clocks, to use either chronograph, and a small battery of six cells furnished a light for the mire, which could be used by day and night. Electric bells in each sleeping room were rung by a single switch key in the observing room, to awaken such men as were detailed for the last half of the night. These observers had simply to adjust the corresponding switches, in the separate rooms, when they went to sleep. They were awakened in season to get a lunch before going to the observing room, and in the latter there was no interruption made by calling, and the observations of the last half often joined those preceding with not more than a gap of one or two minutes between stars.

After mounting the instrument, a determination of the



OBSERVATORY BUILDING AND PHOTOMETER HOUSE.

graduation errors of the 15 ° divisions was made, the flexure was measured in many consecutive series, and the errors of pivots were investigated. These measures were intended to confirm, and to complement much more extensive ones, which had been previously made at Anbany. On the completion of these investigations, and after the first observations on the programme had been begun, Professor Boss left San Luis, finally, early in April, to return to this country by way of Europe. After his return from abroad, he was kept in constant communication with the working party, and the preliminary reductions of current observations were forwarded to Albany for the final computations.

Some account of our manner of living can follow, in this place. Quarters and office furniture, lights and stoves were supplied by the observatory; each one furnished his own sleeping room, and the mess outfit was mainly supplied by a common assessment. Expenses for our table were on about the same scale as would be found customary here. Servants wages were not high, except for the services of a professional man cook, employed for the greater part of our stay. Vegetables were abundant, and of fairly good variety. Fruit of some kind could usually be obtained at all seasons, but oranges and grapes were the main resource, each during a long season. Meat was inexpensive, as compared with this country, if only beef and lamb be included; pork in all its forms was dear, and but little in demand. Turkeys and fowls were abundant in their seasons, and reasonable in price. Eggs on the contrary were always dear, and butter a luxury in price, and always of the unsalted kind. Some variety was furnished by the game of the country, but always from our own guns, as none is for sale in market; partridges of four varieties, ducks, pigeons, and hares were to be had, by the energetic in pursuit of them. Not seldom there were strings of game that included nearly all of the above selection, hung to the roof of the corridor, safe to keep for a week in winter weather. Following the custom of the country, and of the continent of Europe, the day was begun with the *desayuno,* coffee and bread, with perhaps fruit or eggs in addition. The most substantial meal is usually the real breakfast, served about noon or just preceding. After this, a couple of hours for a siesta, or for outside recreation was usually in order. Dinner was served earlier than is the custom of the country, when the hour often is as late as eight o'clock in Summer. Six o'clock was the hour that usually fitted in best with our observing arrangements. This allowed time for the afternoon series of observations, and an hour was taken by those who were to continue into the first half of the night. At the change of observers, there was lunch, with coffee, for all of both parties that chose to indulge. The service of the table and of the rooms was performed by native boys, whose willingness, and general faithfulness should be gratefully recalled. If we exact, and —sometimes—obtain greater efficiency in this country, there are compensations in a life where one takes it easier, and lives perhaps quite as happily.

In this story, there remains the fitting of the details of our manner of living into our big scheme of work. The observing plan may be divided into the two classes, fundamental determinations, and differential work. Many details are common to the two classes of observing, the principal differences being shown in the arrangement and distribution of the observations. For the fundamental work, the azimuth was to be determined from successive transits of circumpolar stars at both culminations, and the clock correction and rates were to depend upon the transits of groups of stars differing twelve hours in right ascension. In order to obtain this distribution of transits, the fundamental observer began usually at from three to four in the afternoon, taking as many bright primary fundamental stars as possible, with the corresponding Nadirs, Mires, and refraction record. The first hours would be observed alone, reading the circle microscopes along with the transits. Towards dusk the microscope reader would join him, as the transits of fainter stars, still of the fundamental class, became possible.

Following the break of the dinner hour, the observations would come more closely together, and for a large part of the work a third man would make the telescope settings, governed by the program on the observing list. The telescope observer had only to make his record, and at once get into position for the next transit; and in hurried periods, even this record could be advantageously made by the man who made the settings.

The services of this third observer would not only increase the number of observations possible, but diminish also the strain consequent upon having many and varied details to be attended to by one or two observers. These three would carry the observing up to near the middle of the night, mainly of stars of the various fundamental classes, though stars from the general list were included when there were gaps that permitted it. The second set of observers began work upon the general list of stars, usually with a very brief gap, only, between the sets. A third man, for making the settings, but rarely came on during the last half, or perhaps for only a short period, during which the observing list was crowded with stars, as any full list will have such condensed regions. At the finish of their turn, the original fundamental observer returned, alone, to obtain the transits corresponding to his circumpolar observations and to the clock stars, made twelve hours earlier. There was sometimes a gap between the end of the last half of the night at daybreak, and the morning series of observations, but not a long one; and the morning series was often continued as long as the bright sky would permit of daylight observations, perhaps up to eight or nine o'clock. There would often be quite sixteen hours of practically consecutive observing on a single date. This would be recorded in two sets, that of the fundamental observer including all his observations during twenty-four hours, and even those of an extra lot of observations, the morning of the day in which he began his turn of six consecutive days at fundamental work.

The staff included five telescope men, of whom three divided the fundamental work, the other two confining their observing to the general list. Each fundamental observer, after a week on duty, would have a week free; and, during the week next following, would take a part in the work of the last half of the nights, on the full list. One part of the plan was to have the observing of the last half so distributed that no observer would be on duty for two, in succession. One's natural hours of sleep could be better provided for, in this manner. While there were five microscope readers available, these could also distribute the night work in much the same manner, so that they could have alternate nights free throughout. On the departure of two of the men, the work of the remaining microscope readers was increased, in number of hours; but by the time the third man had gone, the observing requirements had been much reduced, through the partial clearing up of the list. The work was a severe strain upon eyesight, and that of two of the staff gave out so completely that they had to abandon observing, while the eyes of at least two other observers had felt severely the tax. In the two cases of giving up the work, the eyesight of neither observer had probably ever been good enough to have safely undertaken such a line of work, but it is believed that no injury of permanent nature has resulted in any of the cases recorded. Daylight observing is especially trying, having the glare of the bright sky as a background, against which to pick out, and hold, a faint and usually quivering point of light. The change from the telescope field, to the illumination of a hand lamp for setting the telescope, and to the bright illumination falling upon the small figures of the observing catalogue, produced strains upon eyesight, which were greatly diminshed by the help of the extra man to set, while his changes of illumination were not so complex.

In general, the daytime observing at San Luis was better than we experience at Mount Hamilton. The atmosphere was usually steadier, and the stars easier to hold in view against the background of bright sky. We have supposed our difficulty in daytime here to be due to the ascending air currents, set up on the slopes of the mountain. The observing of a bright star was often improved by using the diaphragm, on the objective, as the darkening of the field gave a better contrast to the image of the star, though its light would be correspondingly diminished.

In daylight, from six to twelve observations per hour would usually be made, depending upon the distribution of available stars. Fifteen or more could be included as the sky darkened. With the aid of a microscope reader, in dark sky, thirty to forty per hour would be taken; and with an extra man to set, the number could be increased to fifty and upwards. Nadirs had to be interspersed, three each regular series, and corresponding numbers during the daylight shorter turns. During all the fundamental observing, there were always special stars to be selected, and this involved some waiting; while during the last half of the night, once the necessary clock and azimuth stars had been included, there were generally no waits for transits, until the list was nearly cleared up. In the progress of the seasons, all the fundamental stars would be observed, by this arrangement of program. The circumpolar stars furnish a determination of the position of the mire, and all the primary clock stars will be knit together with a basis of twelve hour groups.

The fundamental observing began April 6, 1909, and was finally terminated in June, 1910, with about three hundred series. The observations on the general list began April 8th, and the last star was observed on January 11, 1911, though observing for personal errors, and various determinations remaining, was continued up to the end of January. Less than twenty-two months were employed in the observations, though three years had been regarded as the best probable solution of our big scheme of observation. The average number of observations per night during the first year was 214; the average per series was 140, and the full nights averaged 295, including daytime observations. These figures would be slightly increased, by taking the averages in the year beginning two months later, and especially after the end of June, when the third observer worked during the first half of the night. The largest month was December, 1909, with 6,500 observations, the smallest during active work was September, with 3,100. After the month of May, 1910, the Sunday night observations were discontinued; and after July of that year, the observations were mainly confined to the first half of the night. During the first year, three quarters of the observing was completed, one-half of the stars having been checked off, as fully observed. At the end of observing, there had been made slightly over 87,000 observations, in twenty-two months, an average of nearly four thousand per month; while for the first fifteen consecutive months the average was above five thousand per month. There were individual series that included 240 observations, and the maximum for the two series of single date rose to 480. One special series contained

334. The largest week gave 1890 observations, and there was no single week, which included the full six nights, without at least one half-night having been lost by clouds. After the first two months, the average per week had risen to above 1,000, and this average was maintained up to the practical finish of the bulk of the program, in November, 1910. Each fundamental observer had as many as one thousand observations in one week, to his credit. The whole number of nights employed was 456, an average of 191 observations per night, or an average of 133 for each of the 654 series. The collimation determinations, by the fundamental observers, were not included in the count of observations; and special observations for value of the screen, and for other purposes, have not been included.

The description of the methods of observing, and of the conditions of climate, have been sufficiently detailed to show how so large a number of complete meridian circle observations were obtained, in the period covered by the active work. But it is not possible to describe the spirit back of this record. Every member of the staff worked energetically, and without any urging, at all stages of the observing program; they seemed to be imbued with a spirit of loyalty to the scheme, that was enough to meet every requirement. The record of the men that took part in the observations at San Luis follows, condensed into round numbers. Of the telescope observers, with previous experience, three were from the staff of the Dudley Observatory; and two from the Lick Observatory, Mr. Sanford and the writer. The microscope readers were all recent graduates of engineering schools and universities. Seven institutions are represented, in the list of men; Lehigh, Union and Syracuse, with two each; Boston, Troy, Michigan and Minnesota, with one.

TELESCOPE OBSERVERS.	
R. H. TUCKER	20,800
A. J. ROY	20,400
W. B. VARNUM	20,400
M. L. ZIMMER	13,700
R. F. SANFORD	11,700

MICROSCOPE READINGS.	
J. M. FAIR	12,500
M. I. ROY	3,500
P. T. DELAVAN	16,000
R. F. SANFORD	6,300
M. L. ZIMMER	4.800
L. Z. MEARNS	18,800
H. JENKINS	20,600
Fundamental and Miscellaneous	4,500

During the early part of the observing, Messrs. ZIMMER and SANFORD read the circle microscopes for each other; and the fundamental observers read their own circles, during most of the daylight work.

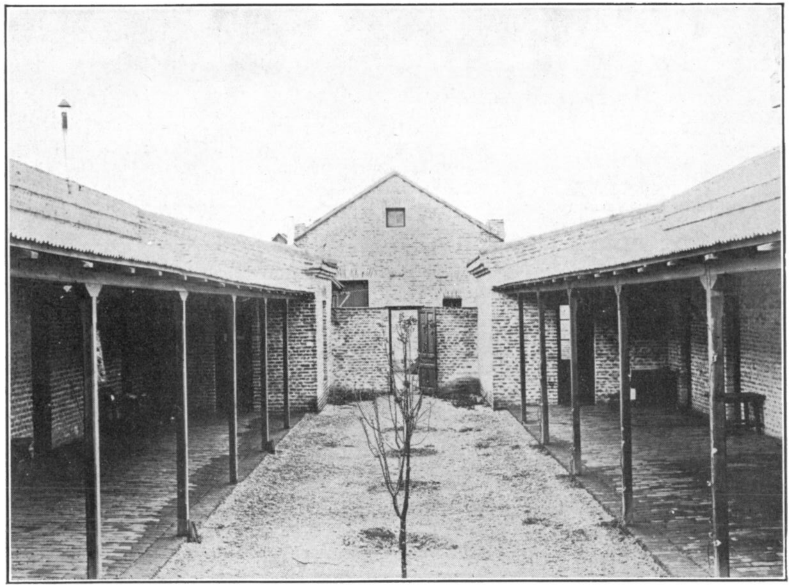
The observing list included quite precisely 15,000 stars, of which 1,600 were fundamental stars of some degree of precision. The general list was planned to contain all southern stars below — 30 °, that had been observed with meridian circles previous to the epoch 1875, and practically all stars, in that region, of seventh magnitude or brighter. The full list was to be given four observations of each star; except that in the zone — 20° to — 30°, which could be well observed at northern stations, two observations would be accepted for a position. But practically all the stars in this zone were eventually given four observations. Among the stars of the fundamental list, eight observations was the rule for those south of — 30°, and four for those in the belt — 20 ° to — 30 °; and the greater part of these last eventually received eight. The secondary fundamentals, of medium strength, were given twelve observations each. The primary fundamentals, of the best class existing in the southern sky, were given sixteen observations. The list of twenty-eight circumpolar stars for azimuth were given thirty-two determinations, by the fundamental method, distributed as nearly as possible between the two culminations, for each star. These stars were used for azimuth, in the observations of the general list, but such observations of the circumpolar stars were not counted towards the determination of their positions. Nor were the observations of primary fundamental stars, during the observation of the general list, reckoned in the completion of the quota for stars of this class.

In the general list, the lower culmination of circumpolar stars was counted separately, and the full number of observations were given each culmination; but, for stars within five degrees of the pole, observations at either culmination might be reckoned in the quota for the star. The primary clock stars, the best determined in the sky, were to receive at least sixteen observations each, in fundamental series; but this number was greatly exceeded, in the case of by far the greater part of them. The existing position of these stars are to be adopted, in reducing the work; the observations of all remaining stars on the lists are to contribute towards new determinations of position. In observing the general list, primary and secondary fundamentals were observed, with a distribution of one star every ten degrees of zenith distance, including refraction stars up to 82° from the zenith. Fundamental series included greater numbers of standards stars, at all zenith distances. There were about three hundred primary stars, including the primary clock stars, and nearly two hundred and fifty secondary stars; the remainder of the fundamental list were of less weight. From —20° south, the fundamental list contained nearly four hundred stars of the first two classes, of which ninety were circumpolar, and required observations at both culminations. In the full fundamental list for observing at San Luis, over nine hundred stars were south of —20° and the remaining six hundred and fifty were distributed as far north as + 49° declination. Observations of these Northern stars are planned for Albany, to combine the results of the two sets of observations, made with the same instrument.

The observations of every star were distributed equally, as nearly as possible, between the four positions of the instrument, Circle A east, and A west, and Circle B east, and B west. The instrument was usually reversed every two weeks, one week having been devoted to observations made with each circle. Towards the close of the work, strict rigor was not necessarily exercised in making the last observation of a star, but it was always considered as more urgent to have the two positions of the instrument, clamp east and clamp west, equally represented in the total, even if the two circles were not as evenly observed. The final record shows how well this distribution was obtained, without having striven for perfect figures.

BE	21,200	West	43,800	Circle B	43,000
AE	22,000	East	43,200	Circle A	44,000
AW	22,000				
BW	21,800				

The collimation was observed about once a week on the average, and was found to exhibit a well defined and relatively large rate depending upon temperature, such as had been shown



INTERIOR COURT, WITH OBSERVATORY AT EAST END.

in the previous record of this instrument, the Pistor & Martin's 8-inch transit circle of the Dudley Observatory. The instrument had been mounted more than fifty years, one of its important contributions having been the *Gesellschaft Zone* next north of the equator. It is provided with two three-foot circles, divided to two minutes, the graduation having been recently renewed. Flexure was again measured at the close of the work in San Luis, the amount being about one and a quarter seconds, including the circle flxure. For modern meridian circle work, the various classes of personal errors must be investigated, as well as the errors of instrument, and the corrections due to refraction. These personal errors can be briefly enumerated here.

For each of the telescope men it was necessary to have a determination of the magnitude equation, and of the correction due to the direction of the star's apparent motion during transit. The telescope was provided with three groups of transit wires, nine in each group, and a transit over two groups, of which one was screened, gave a determination of the difference between full brightness and reduced. If all three groups were observed, the determination was correspondingly strengthened. The telescope was fitted with a diaphragm, which reduced the apparent brilliancy of the star by one and one-half magnitudes. The screen, which fitted on in front of the diaphragm, further reduced the brightness by four magnitudes. Both were manipulated from the eye end, by strings conveniently located within reach of the observer, who could regulate the character of the transit quickly. The screen could not be employed independently of the diaphram, so that he had a choice of 1½ and 5½ magnitudes, in reducing the brightness. These were used regularly in observing all stars that were brighter than sixth magnitude, as a rule; the brightest fundamental stars were screened, and fainter ones diaphragmed. The corresponding reductions for magnitude equation, in place of being applied over a range from first to tenth magnitude, will be needed, in general, for the range from sixth to tenth. Some modern instruments have been provided with a larger assortment of screens, so that greater uniformity can be secured in the apparent brightness of the various classes of stars under observation. Several hundred transits were observed by each telescope man, for the determination of the magnitude equation, naturally the largest number falling to the fundamental observers. The difference between day and night observation of bright stars remains, as a problem difficult of satisfactory solution. Full daylight may be estimated to cut down the apparent magnitude of the star, as compared with darkness, by something like five units of the scale.

For the correction to transit, and to observed zenith distance, depending upon the position of the observer, about four hundred observations of stars within 5 ° of the zenith were made by each observer, facing north for one observation, and facing south for the succeeding observation of the same star. From twenty to forty stars per night were combined in this manner, into one series. There still remains the question whether the corrections depend only upon the apparent direction of motion; or whether they may be influenced by the speed, at various declinations. The matter is further complicated by the difference in the magnitude equation, which may be found for any observer, when facing north or south. But, in any case, the careful observation and discussion of the relative corrections thus determined for each observer may be expected to cut down the systematic error, to a large extent.

Careful determination of the screen value, the amount by which the star's brightness is reduced, were included in the program. The value derived will depend somewhat upon the scale of magnitudes adopted for the comparison stars. The existing scale of visual magnitudes, such as is exhibited in the Durchmusterung, in the Gesellschaft zones, and in the Cordoba Catalogues, is found to be in good general agreement with the most extensive photometric work, like that of Harvard and Potsdam. Recently determined scales of correction to these photometries, like that quoted in the *Preliminary General Catalogue* of Boss, are not confirmed by direct reference to the sky. Many photometric determinations of the faintest stars, however, will undoubtedly prove to assign too faint a magnitude, when compared with the visual scale.

Determinations of the difference between eye and ear observations, and the transits by chronograph, were made by some of the telescope observers, using stars between 80 ° and 87 ° declination for this purpose. In our observing it was the usual practice to record transits of stars above 85 ° by the eye and ear method. The chronograph transit is usually found to have been recorded later. This would be in accord with the practice of tapping the recording key when the star is seen bisected, in place of trying to tap simultaneously with the bisection.

The refraction correction should be investigated at every observatory, especialy when determinations of a fundamental character are involved. The use of the same instrument, at both Albany and San Luis, gives an opportunity for eliminating some instrumental peculiarities from the combined determination of the refraction. Stars were observed at San Luis up to 49 ° north declination, at 82 ° zenith distance, and southern circumpolar stars, down to 65 °, gave an equally large zenith distance subpolar, on the opposite side. About three thousand observations of fundamental stars, from 68 ° to 82 ° zenith distance, on both sides, are available in the San Luis work, for the determination of the local effect. The refraction for any particular site can be determined fundamentally by the use of the same circumpolar stars, at both culminations. For the standard azimuth stars of our list, there are some thirteen hundred circumpolar observations available, in the fundamental series alone. The nearest star to the south pole, *Sigma Octantis,* only 46 ′ from the pole, was observed sixty times, counting both culminations. It is not nearly as easy to observe as *Polaris,* which is 1 ° 10′ from the North Pole, as the magnitude is only 5.6, and this is a difficult star to see in daylight, while *Polaris* is easy of observation at any hour of the day, up to full noon. In fact, the whole southern circumpolar region is lacking in bright stars, there being but one star brighter than three, and only three stars brighter than four, within thirteen degrees of the pole. There are no stars within five degrees of the south pole as bright as fifth magnitude.

Another investigation, that involves both atmospheric and instrumental corrections, is the comparison of direct observations, with those made by reflection of the star's image from a basin of mercury. In most observatories, where this scheme of observation has been tested, there has been found a small difference, perhaps nearly constant, between the results of the two observations. This has sometimes been explained by theories of refraction errors, due to abnormal conditions in the atmosphere of the room. But it may be more commonly attributed to error in the effect of flexure, as determined for the telescope and circles. In San Luis, we secured over four hundred reflection observations, in twenty series, each observed on two nights. Except for slow moving polar stars, like *Sigma Octantis,* it is not possible to make the change of position, from direct to reflected, at the same transit, and the stars were selected so that there would be pairs at nearly the same zenith distance, one star of which would be observed direct the first night, and the other reflected, while the order would be reversed on the succeeding night. A pair each ten degrees, on both sides of the zenith, was selected, within the limits possible for reflection observations. Systematic errors of observation, and of reduction, would be pretty closely eliminated in the subsequent discussion of the pairs of observations. It requires a perfectly calm night for reflection observations, but under good conditions the image at transit is often perfectly satisfactory. The small outstanding difference, R—D, can not be taken as invalidating the law of physics, that angles of incidence and reflection are equal, since the observed difference is unquestionably due to sources of error in instrument or reductions, and is so small that it cannot be treated as affecting the truth of the theory. The small size of the difference shows how closely we have finally come to the elimination of errors of instrument, atmosphere, and observer.

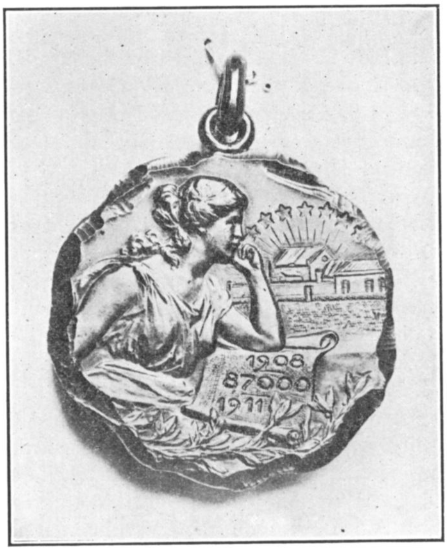
The computations for the full reduction of the San Luis Observations will be done at Albany, where the headquarters of the Department of Meridian Astrometry of the Carnegie Institution are located, and where there is a large staff of computors. During the active prosecution of the observing program, only the preliminary steps of the reductions could be taken. The men, not at work on the preceding night, read off the chronograph sheets in the morning, and all the microscope means were taken, also, as a rule before noon. From the transits recorded, and the circle readings, the star could be exactly identified in the list, and checked off, so that it would not be reobserved on the night succeeding, in the same position of the instrument, when such observation was not required. The means of all transits were taken, later on, and thoroughly checked, and the graduation corrections and runs corrections were entered for the circle readings, which were also independently checked. The material of observation for the star's position was then entered upon the proper computation sheets, for right ascension and declination, and these sheets were copied in duplicate, and the copy was checked by reading from the orginal record. One copy of these computation sheets was despatched by registered mail, while the other was retained until notice of the arrival of the first copy reached us. As all computations are to be made in duplicate, there was no extra labor involved in the copying. For final security, the zenith distance books were copied in full, with the entry of the corresponding corrections, and the sheets of copy were sent by mail. This last process was performed mainly by native copyists, both men and women, paid by piece work. The absolute security of every stage of the computations was thus secured, even if the original records had been lost in transit. In sending very large amounts of mail matter in this way, it is worthy of record that not one sheet was lost in transit, and the original observing material was also finally safely despatched by freight.

The dismounting of the instrument was begun upon the first of February, and as soon as the greater part of the equipment had been packed, mostly in its original boxes, the assistants began to go, some returning to this country by way of Europe, the extra detour involving neither greatly increased expense, nor much extra time, beyond what was spent in traveling after arrival in England. The one big single parcel of freight was the reversing carriage, which was shipped entire. As the box enclosing it was too large to be passed through any single door, the wall of the observatory outer court had been left open to receive it. When this box was to be taken out, the door in the wall was removed with its frame, and the wall was afterwards rebuilt. The observatory building was provided with large double door. Two of the staff accompanied the freight from Buenos Aires to New York, sailing on March 8, 1911. There were some details to arrange, for the disposition of the observatory, in the succeeding month, and the last member of the expedition left San Luis on April 3rd, to sail five days later, direct to New York.

It appears proper to give some account of the share of the members of the party in the work of the observatory, to complete the record of observations, which has been noted already in these pages. Messrs. VARNUM and TUCKER were on the ground during the building of the observatory, and were among the last to depart. The second party included Messrs. A. ROY, ZIMMER, SANFORD, FAIR and DELAVAN. The first three named, remained to the close of the observing; Mr. FAIR only wished to remain during one full year, and left in February, 1910; Mr. DELAVAN had increasing difficulties with his eyesight, and had finally to abandon the work, leaving in May, 1910. In September, 1909, three extra men arrived, to bring the force to full efficiency; Messrs. M. ROY, MEARNS, and JENKINS. The microscope reading proved to be too severe eye strain for the first named, and he gave up, and left us in February, 1910; the other two observed to the close. There was no distinction in the manner, and in the spirit with which all the staff took up their work; the successful issue of the entire plan is sufficient evidence of this. Mr. A. ROY was in charge of current computing, Mr. VARNUM of the electrical work, and Mr. ZIMMER of the clocks.

The closing of such a project must always bring up sentiments of varied nature. The expedition had been successful in all its undertakings, there had been no difficulties in construction, in transport, in the installation of the equipment, nor in the prosecution of the work which had not been easily overcome. There had been no social problems, difficult to solve, in the living together, and working in unison of a staff of men, gathered in part with some haste. Except for the injurious effect upon eyesight, there had been no illness nor accident, beyond the indispositions of a day or two, likely to occur under any conditions of living. It is not likely that any man who took part in the expedition will entirely regret having done so. For some, perhaps, the recompense may be best found in the satisfaction of having helped carry through to a finish, a scheme of such magnitude. Some of the men engaged have not intended to follow the profession, to which this expedition introduced them. But in any other technical line of work, they will eventually experience the help of the training which it gave, in careful and exact instrumental work, and in the line of computing, though the processes used may have been of the simplest and most routine character.

The successful finish of the work of the observatory was recognized by the citizens of San Luis, in the form of a banquet, held on April 2nd; and in a handsomely engrossed testimonial to the President of the Carnegie Institution, with the direct presentation of the gold medal, reproduced here in photographic form. Since reproductions of both have already been published, it seems not inappropriate to include them here. The inscription on the medal reads, in translation:



GOLD MEDAL PRESENTED BY CITIZENS
OF SAN LUIS.

THE PEOPLE OF SAN LUIS,
TO RICHARD H. TUCKER.
OBSERVATORY OF SAN LUIS.

It was my pleasure to present the testimonial, personally, in the month of May, at Washington. And, there, to renew a friendships with which I had been honored before my connection with the Institution, and which had been cordially exhibited during the course of that connection.

TESTIMONIAL ACCOMPANYING MEDAL PRESENTED BY THE PEOPLE OF SAN LUIS, ARGENTINA, TO PROFESSOR R. H. TUCKER OF THE CARNEGIE INSTITUTION.

[*Translation.*]

SAN LUIS, April 2, 1911.

THE PRESIDENT OF THE CARNEGIE INSTITUTION,
Dr. R. S. Woodward,
Washington, D. C., U. S. A.:

The city of San Luis has been honored by the installation, at the foot of its mountains, of one of the historical telescopes of the world, for the purpose of recording a chapter in advanced science. The horizon of our pampa, parting its curtain of clouds, has freely allowed to be pictured the beautiful constellations of its sky.

It is most satisfactory to us to recognize the excellence of the work done at the observatory of San Luis, and its great usefulness for the advancement of astronomy.

The plan of Professor Boss, of Albany, Director of the Department of Meridian Astrometry, has been executed with complete efficiency by the staff of the observatory: Messrs. R. H. TUCKER, A. J. ROY, W. B. VARNUM, M. L. ZIMMER, R. F. SANFORD, P. T. DELAVAN, J. M. FAIR, M. I. ROY, L. Z. MEARNS, and H. JENKINS.

The Carnegie Institution has in this manner linked the name of San Luis with posterity, and our people, thus distinguished, have expressed their spontaneous feelings toward Professor R. H. TUCKER, by offering him a gold medal and a public banquet on this occasion.

The natives of San Luis, with these sentiments, send their most cordial greeting to the honored president of that institution, recognizing its noble mission of stimulating the cultivation of the sciences which most honor the progress of humanity.

At the horseshoe table of the banquet, were gathered of the best in San Luis; and their presence, with the sentiments expressed, could not fail to be a source of gratification, which was mingled with the regret of parting. Many of the guests were at the railway station, the following night, when the train bore me finally from their city. But there must be many *recuerdos* that will remain, from our acquaintance, and often intimate intercourse.

The observatory building, and the dwelling, will be probably eventually used by the Argentine National Government, as the basis for the development of some educational project. The Astronomical and Mathematical Section of the International

Scientific Congress, that met in Buenos Aires, in July of the Centennial year of Argentine Independence, 1910, passed a resolution, recommending to the National Government that the San Luis Observatory be preserved, for the purposes of future astronomical observations. The plan and aims of the observatory had been described in a paper, in Spanish, presented before this Congress. The buildings were left in substantially good order, and though time may work its damages, the two-foot brick walls of the observatory are likely to stand for a long period, and the concrete piers may be trusted to withstand most natural and artificial ravages, as a permanent memorial of our expedition.